Driving by Driverless Vehicles in Urban Environment*

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Abstract. A number of the Intelligent Transportation System (ITS) solutions have been implemented in conventional vehicles in recent years. In the not too distant future driverless vehicles will share the roads with vehicles driven by human beings. In this paper, a novel algorithm for switching from one driving maneuver to another is proposed. The interface has been developed in C++ Visual Studio and using a 3D simulator with the data provided by a GPS and lidar sensors. Specific driving tasks such as lane following, curve driving and roundabout driving have been analyzed and tested with good simulations results obtained.

1 Introduction

Nowadays, multiple improvements in road monitoring and partial vehicle control are being deployed in conventional vehicles under the umbrella of the so called Advanced Driver Assistance systems (ADAS). Some of these solutions have been welcomed by drivers and already accepted as comfort accessories (like *Cruise Control* and *Assisted Parking* systems), while others remain important topics in the Intelligent Transportation Systems (ITS) research, such as perception systems, cooperative driving, safe and reliable driving, etc.

Most accurate vehicle control systems use global positioning (Differential GPS) data to perform the automatic control over the steering wheel [1] [2]. The need for accessing a central base station is the main weakness of GPS signal-based navigation methods. Recent research shows that this drawback could be compensated by fusing GPS with vision information, what was performed for the lane border detection task [3].

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Lidar sensors have typically been used for the task of scanning (detection) vehicle's immediate road traffic environment, showing good results even under real-time constraints [4]. Other applications such as a car-following system to track a preceding car while maintaining a safe separation distance are also based on the lidar sensors[5].

Since DGPS and lidar sensors have both being widely accepted by the autonomous systems research community, this work is also using the lidar sensor for the purpose of detecting the presence of others vehicles and/or pedestrians while the lane following task is performed based on GPS data obtained.

The driverless vehicles-based road traffic modeling environment - ICSL Simulator - was initially developed by [6]. The simulator allows the exchange of different control strategies such as path generation methods and sensor fusion techniques based on the real data obtained from GPS and lidar sensors in real-time. An interface has been developed in C++ Visual Studio. The work presented in this paper reviews the performance of the developed modeling environment in performing both the basic driving tasks as well as high risk driving maneuvers like overtaking maneuver on two way roads.

This paper is organized as follows: section 2 explains the simulator used to test the developed driving algorithms which are described in section 3, while the obtained results are presented in section 4. Finally the conclusions are drawn in section 5.

2 ICSL Simulator

The cooperative driving paradigm has been developed for computer-assisted experimental vehicle platforms -Cybercars- [7]. Using these vehicles, the concept of decision making for driverless city vehicles has been simulated and thereafter tested on real road test tracks. These driving maneuvers have included the most basic tasks, as well as more complex ones such as: platooning, intersection crossing, emergency stopping, overtaking (but, implemented in open loop control), etc[8].

The obtained results pointed onto the possible improvements with respect to: sensor fusion, decision and control as well as driving maneuvers [6][8].

Figure 1 shows various road traffic environments and obstacles used in the simulator (from the higher left to the lower right part): roundabout, overtaking, initialization of the cybercars and path following with pedestrian detection.

The Interactive Interface

Before to start each maneuver, the following set of steps is normally required:

- *To activate the simulator*: different road traffic set-ups can be loaded (intersection, straight segments, urban streets, roundabouts, etc.).
- *To start the program in C++*: each maneuver is associated with a specific road traffic environment, and related map.

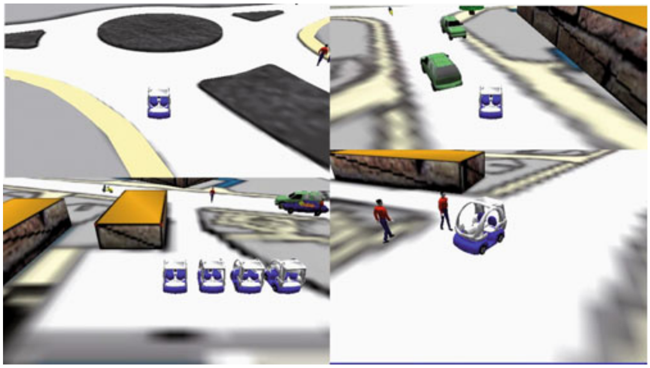

Fig. 1. 3D Simulator for Cybercars (ICSL)

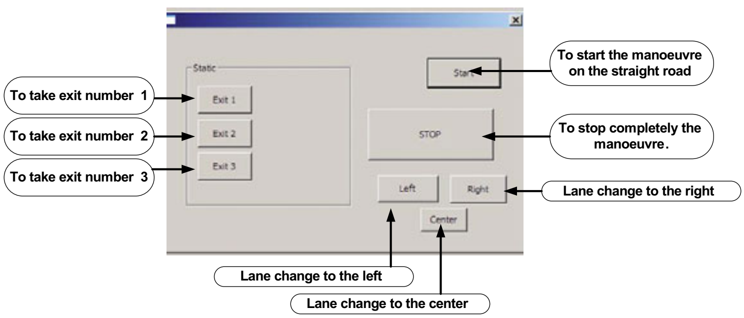

Fig. 2. Interactive interface of the roundabout maneuvers

– *To start the maneuver*: each maneuver has its own interface. For example, figure 2 shows the interface for the roundabout maneuver. All the maneuvers have a start and stop button.

3 Control Scheme

This control scheme is completely modular, so each block is added and tested. The modularity of the scheme allows the testing of different control strategies without modifying the global structure. Figure 3 shows the proposed control scheme as follow:

World Information and HMI

World information and HMI block is in charge of storing the data coming from the sensors. Moreover, previous information, such as signal position, maps or special situations, among others, are read from the initialization files. A Human-Machine Interface allows the change of preferences as well as lane reference,

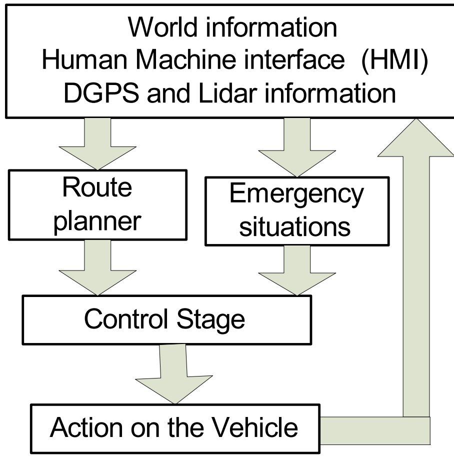

Fig. 3. Control scheme for maneuvers on urban roads

emergency stop, etc. It receives the information from the vehicle using the GPS and lidar information. The GPS gives the information a 2-dimensional Cartesian Coordinate system. The lidar information is used to stop the vehicle in a case where there is an obstacle in front of the vehicle. The driverless control is programmed to follow a route (predefined or dynamic), however, the user can change the lane, route and speed, among other parameters.

Route Planner

The Route Planner reads the information coming from the first block, and can also generate new information when or if necessary (for instance at a roundabout).The predefined points on the map come from a XML file. Each route is loaded at the beginning, though other alternative routes can be selected from other map files. For example, in the roundabout maneuver a dynamic map generator is in charge of building the roundabout points, using the parametric equations of a circle, creating the tangent line and defining the input variables for the control stage.

Emergency Situations

This block is executed in parallel with the route planner block, and it can modify the action in the actuator if an emergency situation happens. For example, when a pedestrian is crossing the street, or when another vehicle (or obstacle) is detected during a maneuver execution.

Control Stage

The Control Stage block is in charge of calculating the actions over the vehicle actuators in function of the coming information in the previous blocks. Here, different control strategies can be tested. This block receives the information according to the line reference system (the street in straight segment, and the line tangent on the curve, circles and roundabouts). For example, in case of the steering wheel, two variables have been defined: the distance to the curve and the angular error.

Action of the Vehicle

This module is in charge of moving the vehicle's actuators (steering and pedals). It receives the target from the control block. In the simulator the action interval is [-0.5 ; 0.5] for the steering wheel and [-1 ; 1] for the brake and throttle. It is totally extrapolated to a real prototype.

4 Maneuvers Simulations

Different maneuvers have been simulated, using the control scheme proposed in figure 3, as follow

Path Following

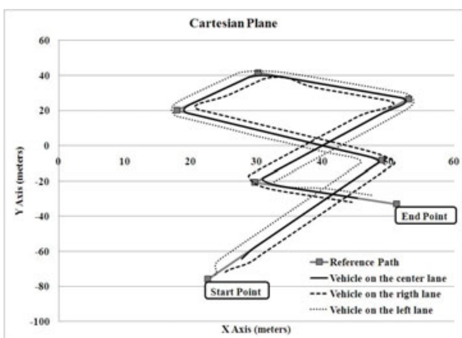

Fig. 4. Lane keeping in the central, right and left line

Figure 4 shows the path following taking into consideration three lanes: central, left and right. The reference paths are the gray lines joined to square points. The lane width is six meters, and the vehicle follows the left lane at 2.5 meters from the central lane. The square dot line shows the behavior on the left lane, the dash line shows the behavior on the right lane, and the continuous line shows the behavior on the central lane.

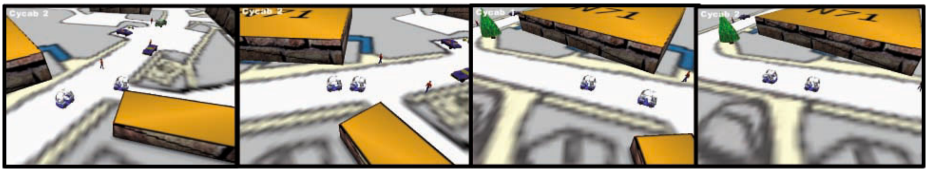

Fig. 5. Stop and go maneuver

Stop and Go, and Obstacle Detection

Figure 5 shows the sequential moments of the stop-and-go maneuvers. The first picture shows when the controlled vehicle arrives to the curve and detects another vehicle ahead of it. The next pictures show how the vehicle stops and goes when the vehicle in front restarts the driving.

Lane Change

Figure 6 shows the behavior when the reference lane is changed. The gray line is the reference line to follow, and the dashed line represents the autonomous simulated vehicle. This maneuver is the basis of overtaking.

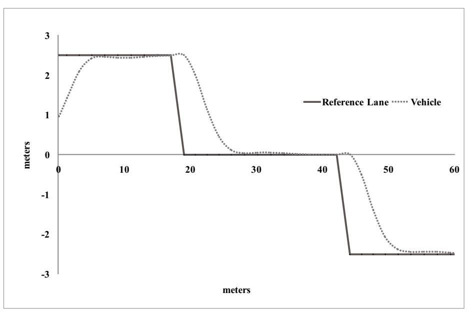

Fig. 6. Lane change in the central, right and left line

Overtaking

Figure 7 shows the sequential moments of the overtaking maneuver. When the vehicle detects a vehicle in the lane at a slower speed, it commences the overtaking maneuver. Once the faster vehicle has completed its overtaking maneuver, then the simulated cybercar returns to the start line.

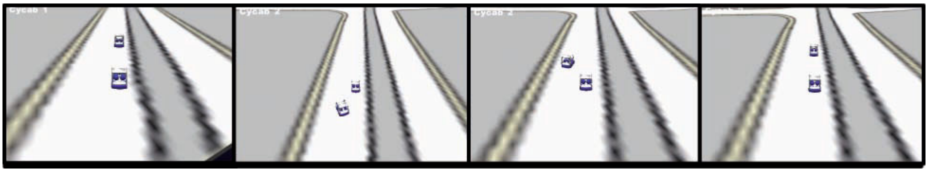

Fig. 7. Overtaking maneuver

Roundabout

Finally, figure 8 shows a simulation of the cybercar entering, driving around roundabout and exiting the roundabout. The start point determines when the cybercar enters the roundabout. Different exits can be selected (depending of the route planner), however, thanks to the interactive interface, the user can select another exit in real time. Then, a new map is generated until the vehicle leaves the roundabout.

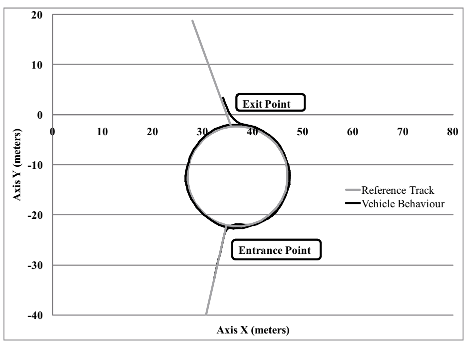

Fig. 8. Roundabout maneuver

5 Conclusion and Future Works

In this paper, different classic and new maneuvers in the ITS field have been simulated and a new control scheme for performing a variety of driving maneuvers in urban road traffic scenarios has been developed.

The control scheme is totally modular. Other control techniques, as well as map generators can be tested without great difficulties. The simulator allows the testing of these algorithms before their on-road testing is undertaken.

Future work will examine an enhanced communication among vehicles in the simulator to permit improved cooperative maneuvers (considering GPS and speed information). Furthermore, the algorithm is scheduled for on-road testing at a research facility in INRIA (France).

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